Rivers in Miniature: The Mississippi Basin Model

by Michael C. Robinson

The decision to build the Mississippi Basin Model (MBM) was a noteworthy undertaking of the Corps of Engineers during World War II. The hydraulic model was a remarkable technological feat in terms of size, innovative design, construction, and resultant contributions to the field of small-scale hydraulics research. Conceived in the late 1930s and built from 1943 to 1966, it replicated most of the Mississippi River and its major tributaries on some 200 acres of funnel-shaped land near Clinton, Mississippi. It offered the appearance of a gigantic relief map with the major streams and topographical features of 41 percent of the continental United States carefully reduced to scale. The facility may be viewed as the Brooklyn Bridge or Hoover Dam of the hydraulics research field—a preeminent structure of unprecedented scale and complexity that represented a rapid advancement of technological frontiers.

The model, designed and built by the Corps' Waterways Experiment Station (WES), also represented a confirmation of the fundamental importance of small-scale hydraulics research within the agency's civil works program. This attainment seems remarkable when one considers that, as late as 1930, many Corps officers and civilian engineers regarded models "as mere toys for youngsters of the profession." Most of the Corps was openly skeptical of the value of models and actually feared they posed a threat to traditional engineering practices based on field data and experience. Until the founding of WES (1929), rivers and harbors work was largely an empirical process and little attention was given to conducting model experiments using the fundamental principles of hydraulic similitude.

The traditional Corps' outlook was apparent during the 1920s as John R. Freeman and other civil engineers campaigned for the creation of a national hydraulics laboratory within the National Bureau of Standards. Some American universities operated hydraulic research laboratories, but the scope of their activities was limited. Freeman, impressed with the hydraulics laboratories of German technical universities, established fellowships for American students to study in Germany and financed the translation of a major German book on the subject of hydraulic laboratory practice. His laboratory proposal received support from Secretary of Commerce Herbert Hoover, most major engineering societies, and federal agencies such as the U.S. Geological Survey and Bureau of Reclamation.

The Corps, however, was a steadfast opponent of Freeman's idea. Its position was carefully stated in a letter prepared for Secretary of War Dwight W. Davis in April 1926:

> The art of river regulation and control has heretofore been developed principally by practical experience in the solutions of problems on a large scale. . . .
>
> The practical, full-scale aspects of the problem are of greater importance and are more dependent upon varying and uncertain field conditions than is common in other branches of engineering. Field experience in the solution of problems of this nature is undoubtedly of much greater value than laboratory experiments could possibly be, and the application of principles evolved in the laboratory to the solution of practical problems in the field must be difficult and uncertain. . . .

The Corps, however, suggested that a laboratory would have "some small measure" of value to the War Department. The debate eventually involved sharp exchanges between Freeman and Major General Edgar Jadwin, Chief of Engineers. In April 1927, Jadwin informed Freeman that, "I do not believe that many of the larger problems involved in the work of the Corps of Engineers, as, for example, flood control on the Mississippi, can be solved in a laboratory." The disastrous 1927 flood on the Mississippi River, support for a Corps laboratory from Lower Mississippi local interests, and a concern that the facility might be placed in the Bureau of Standards prompted the Chief to modify his position. The 1928 Flood Control Act, authorizing the massive, comprehensive Mississippi River and Tributaries project (MR&T),

contained a paragraph enabling the Chief to create a hydraulics laboratory for studying details in conjunction with the flood control plan for the Lower Mississippi Valley.

It seems likely that concerns about challenges to the Corps' preeminence in the water resources field were a major factor in the founding of WES. Major General Lytle Brown, Jadwin's successor, noted that engineer officers opposed the Freeman proposal because they feared other agencies might "dictate to the Corps of Engineers as to how the works entrusted to its care should be executed." Brown, like Jadwin, viewed the laboratory's potential benefits as largely tangential—"specific in character. . . not for general informative purposes."

The task of founding WES fell to First Lieutenant Herbert D. Vogel, who had recently completed a Ph.D. in hydraulics in Germany. The constraints he faced were formidable. He was ordered to create a scientific research facility in the face of lukewarm top-level command interest, intra-Corps apathy and hostility, funding and personnel constraints imposed by the Depression, and even the chagrin of now President Hoover upset by the Corps' opposition to Freeman's Bureau of Standards proposal. His only assets were the impetus of the MR&T project and the support of the Mississippi River Commission staff.

The young officer, in addition to his considerable hydraulics expertise, possessed extraordinary personal magnetism, organizational abilities, communications skills, and bureaucratic cunning. During his tenure as WES Director from October 1929 to August 1934, he founded the facility in Vicksburg, Mississippi; oversaw the construction and operation of credible hydraulic models; established the institution's reputation as a major research center through professional publications; and assembled a highly talented young staff that was, according to Vogel, "iconoclastic, brash, and beholden to no one." Through publications in technical journals as well as visits to universities and Corps field offices, Vogel was able to recruit staff and spread the gospel of small-scale hydraulics research. Thus, WES rapidly evolved from a small organization initially employing crude methods into a research institution of acknowledged scientific attainments.

WES researchers advanced both theoretical and applied hydraulics research due to opportunities provided by the MR&T project and other Corps endeavors. The scope of the institution's work was enlarged by the profusion of civil works projects during the New Deal. Former opponents became ardent enthusiasts; a great number of Corps engineers began to make increasingly difficult research demands on WES, forcing the institution to broaden the scope of its activities and refine the accuracy of techniques. By 1937, WES was conducting hydraulics-related studies for every Corps division but one on a wide range of topics relating to the hydraulic features of dams, river canalization, open river regulation for navigation, flood control, coastal harbors and beaches, and miscellaneous subjects.

The most spectacular project undertaken by this rapidly expanding institution was the design and construction of the largest hydraulics model in the world. The MBM became the Corps of Engineers' principal tool for studying flood control reservoir operations within the Mississippi River basin and for fixing and regulating the Lower Mississippi River channel itself.

The Mississippi basin, which covers some 1.25 million square miles, is about 20 times larger than New England. It extends from the Rocky Mountains to the Appalachians, from just above the Canadian border to the Gulf of Mexico. The watershed contains all or part of 31 states and two Canadian provinces and occupies 41 percent of the continental United States. It is exceeded in size only by the Amazon and Congo watersheds. This vast area is divided into six major subbasins: the Upper Mississippi, the Missouri, the Ohio, the Arkansas–White, the Red–Ouachita, and the Lower Mississippi. The first three contain about 900,000 square miles or nearly 75 percent of the entire drainage basin.

In considering this huge basin as a whole with its 15,000 miles of rivers, its thousands of miles of levees, and its some 200 reservoirs (built, authorized, or proposed), it was apparent that many complex problems faced the Corps of Engineers in the development of flood control measures. Of special concern was the task of operating such a large number of reservoirs to ensure proper coordination of floodwater releases.

Major Eugene Reybold conceived the idea for a comprehensive model of the Mississippi River and its tributaries while serving as district engineer at Memphis, Tennessee, during the 1937 flood on the Mississippi River. He formulated the idea that a huge model could be used to develop plans for the coordination of flood control problems, chiefly reservoir operations, throughout the Mississippi basin. When Reybold became Chief of Engineers in 1941, he was able to put his plan into effect. On 23 May 1942, the Chief met with several WES officials in Washington, DC, to discuss the model. Reybold stated that the model would have a great potential value for demonstrating flood control measures to government officials, laymen, and engineers. He also believed that the model could be used to convince Congress of the necessity for centralized control of reservoirs during flood emergencies in the Mississippi River basin. The Chief also viewed this effort as consistent with plans to implement a large civil works program following the war as an adjunct to demobilization. He ordered WES to conduct a preliminary study, which it transmitted to the Chief on 19 October 1942.

The report suggested that the model would have three principal purposes: to determine methods of coordinating the operation of reservoirs to accomplish the maximum flood protection under various combinations of flood flow; to determine undesirable conditions that might result from noncoordinated use of any part of the reservoir system, particularly the untimely release of impounded water; and to determine what general flood control works were necessary (levees, reservoirs, floodways) and what improvements might be desirable at existing flood control works.

General Reybold was sensitive to the fact that personnel, materials, and equipment were in short supply due to World War II and that civilian labor would not be available to start construction of the model. Thus, he developed the idea of using prisoner of war (POW) labor to prepare the model site, since much excavation would be required to mold the terrain in accordance with the general topography of the Mississippi River basin. He immediately began negotiations through the Provost Marshal General for 3,000 German POWs recently captured in North Africa. He also obtained authority to construct an internment camp, called Camp Clinton, at the model site.

Entrance to the Clinton internment camp. (Harold Fonger)

This strategy had an advantage. The model could be started without waiting for approval of the Bureau of the Budget (BOB) and the War Production Board. The Army granted slightly more than one-third of this request. By August 1943, the Corps was paying over 1,000 POWs from Field Marshal Rommel's elite Africa Corps 80 cents each per day to reshape a 200-acre tract to resemble a relief map of the United States. The employment of POWs was not unusual. Captured German and Italian soldiers were used primarily as contract laborers for farmers, businessmen, and local governments and supported the local economies of predominantly agricultural states. Because of the wartime shortage of normal laborers, their work was essential to labor-intensive agriculture. POWs were even used on flood control projects. Besides building the Mississippi River flood control model, in 1945 German POWs reinforced weakened levees along the Arkansas River during severe flooding in western Arkansas and eastern Oklahoma.

Earlier in 1944, the Office of the Chief of Engineers (OCE) tried to obtain $3 million in appropriations for the MBM project. Because it had not made this request in previously submitted supplemental estimates, the BOB demanded an explanation, called for justification of the funds used for POW labor, and directed the Secretary of War to show how the model met the President's definition for projects that could be started during the war. Essentially this was part of BOB's continuing effort to end the War Department's practice of using military appropriations to finance rivers and harbors and flood control projects the Corps considered essential to the war effort. BOB's principal budget examiner, Charles D. Curran, a former member of the Corps, believed "control of river and harbor work breaks down when. . .performed with so many appropriations."

Secretary of War Henry Stimson tried to convince BOB that neither his department nor the Corps was seeking to manipulate the appropriations process. He explained that the MBM was a central element in the construction and operation of authorized flood control projects in the Mississippi basin. Rather than turning to supplemental funds, the Corps had relied on POW labor. He believed this was appropriate since the project was designed to provide "substantial benefits of a civilian nature for a large portion of the country." If the war should end sooner than expected, the project would generate well-designed plans and a more effective postwar public works program. This argument was effective. BOB approved completion of the model in an attempt to reduce postwar problems. Congressional authorization soon followed.

During World War II, more than 400,000 captured Axis soldiers were transported to the United States for internment at locations throughout the country. Of this total, some 20,000 were sent to Mississippi. Four large base camps were created in the state: Camp Como in the northern delta, Camp McCain near Grenada, Camp Clinton near Jackson, and Camp Shelby in the southern part of Mississippi. During 1944 and 1945, smaller branch camps were built at Greenville, Greenwood, Belzoni, Leland, Brookhaven, Indianola, Clarksdale, Drew, and Picayune.

The site of the Clinton camp was purchased in 1942 at a cost of $49,000. It consisted of 790 acres and would eventually house 3,000 POWs. The compound was enclosed by a 10-foot-high woven wire fence topped with barbed wire. Guard towers equipped with search lights and telephones were placed every 200 feet. Ten feet inside the outer fence was an inner fence of similar height and construction. A deadline was established 20 feet inside the inner fence and marked by evenly spaced white stakes.

The first prisoners began arriving in mid-August 1943. Most had been captured in North Africa and soon adapted to the damp, torrid Mississippi summer. Despite working eight hours per day on the model, the prisoners had a relatively comfortable existence. The food was good and plentiful, and most of the POWs actually gained weight during their confinement. Employees of WES often timed their visits to the model site so they could have lunch or dinner at the camp's mess. In contrast to supply shortages and rationing within the American civilian community, the interned Axis soldiers enjoyed a wide variety of choice foods including the best grades of beef and butter. The camp also featured a canteen where prisoners could buy tobacco, soft drinks, books, periodicals, toiletries, beer, and many articles no longer available to civilians. One POW later recalled that after overindulging in beer, it was hard to spend the morning toiling in the hot sun while fighting a hangover.

German prisoners of war clear the site for the Mississippi Basin Model. ***(Harold Fonger)***

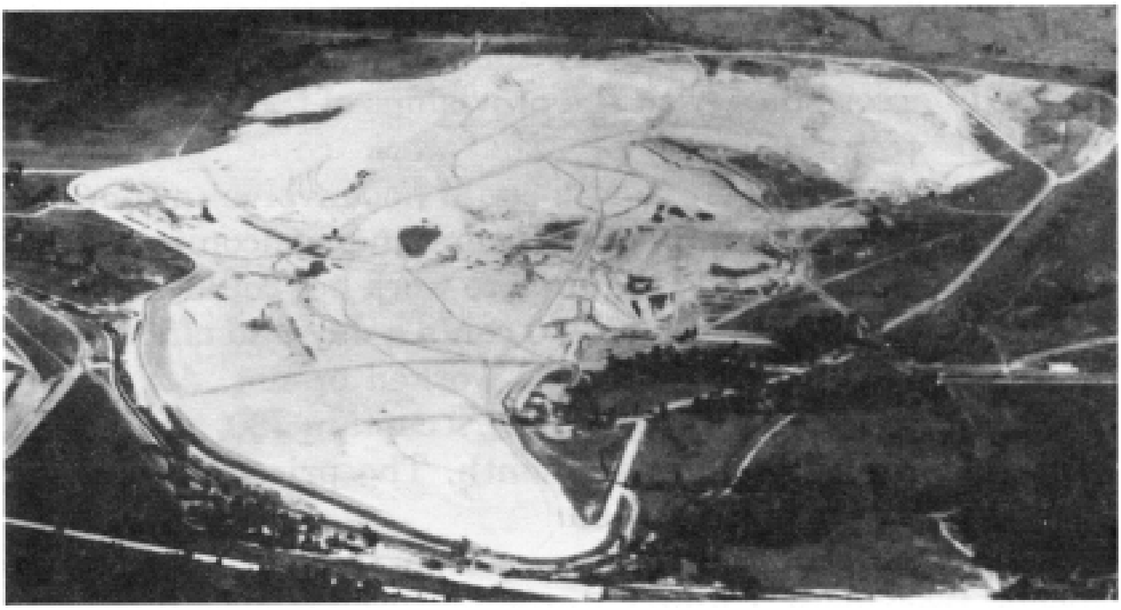
The prisoners devoted their spare time to an array of games and sports including heated competition on a regulation soccer field. They also had access to baseball, basketball, volleyball, and horseshoes. Those inclined toward less strenuous pursuits could use the camp's 6,500-volume library or participate in a theatrical group, a jazz band, and a symphony orchestra.

The day's activities included reveille at 0530, followed by breakfast and a working day that ran from 0800 to 1600 hours. In accordance with the provisions of the 1929 Geneva Prisoner-of-War Convention, the work could be neither unhealthy nor dangerous and could not involve the production of military equipment. Officers and noncommissioned officers (NCOs) were not required to work but could volunteer to do so. Prisoners were paid 80 cents a day and officers and NCOs were paid whether they worked or not. A German lieutenant received $20 per month, a captain $30, and officers of higher rank got $40 per month. The prisoners received canteen scrip in lieu of cash.

The Geneva Convention required that officers receive special treatment. Camp Clinton featured a special officers' compound situated apart from the enlisted men's barracks. During the war, 31 Wehrmacht generals were confined at the camp, including Juergen von Arnin, commander of Army Group Africa, and Dietrich von Cholitz, former commander of Paris, who refused to burn the city when ordered to do so by Hitler. Each of the general's quarters was comfortable, well-furnished, and contained a refrigerator.

Between August and May 1946, when the last POWs returned to Germany, the German soldiers completed much of the preparatory work required for construction of the model. They cleared nearly 600 acres of land, built roads and bridges, and dug drainage ditches as well as storm sewers. Using mainly picks, shovels, and wheelbarrows, the Germans moved more than 1 million cubic yards of earth. The total value of this labor to the project is estimated at $6 million.

Despite a relatively comfortable lifestyle, the POWs attempted numerous escapes. The most spectacular was a 3-foot-wide tunnel dug from a barracks approximately 100 feet from the compound fence. The prisoners made ingenious, small, round cloth packs with drawstring openings to conceal the dirt being taken from the tunnel. They concealed the sacks inside the legs of their trousers. At the model site they loosened the string and scattered the dirt as they labored. The tunnel, which included electric lights, was discovered as it reached within 10 feet of the fence. The burrowers were then sent to a more secure camp in Enid, Oklahoma.



Aerial view of the Mississippi Basin Model during excavation. *(Wateways Experiment Station)*

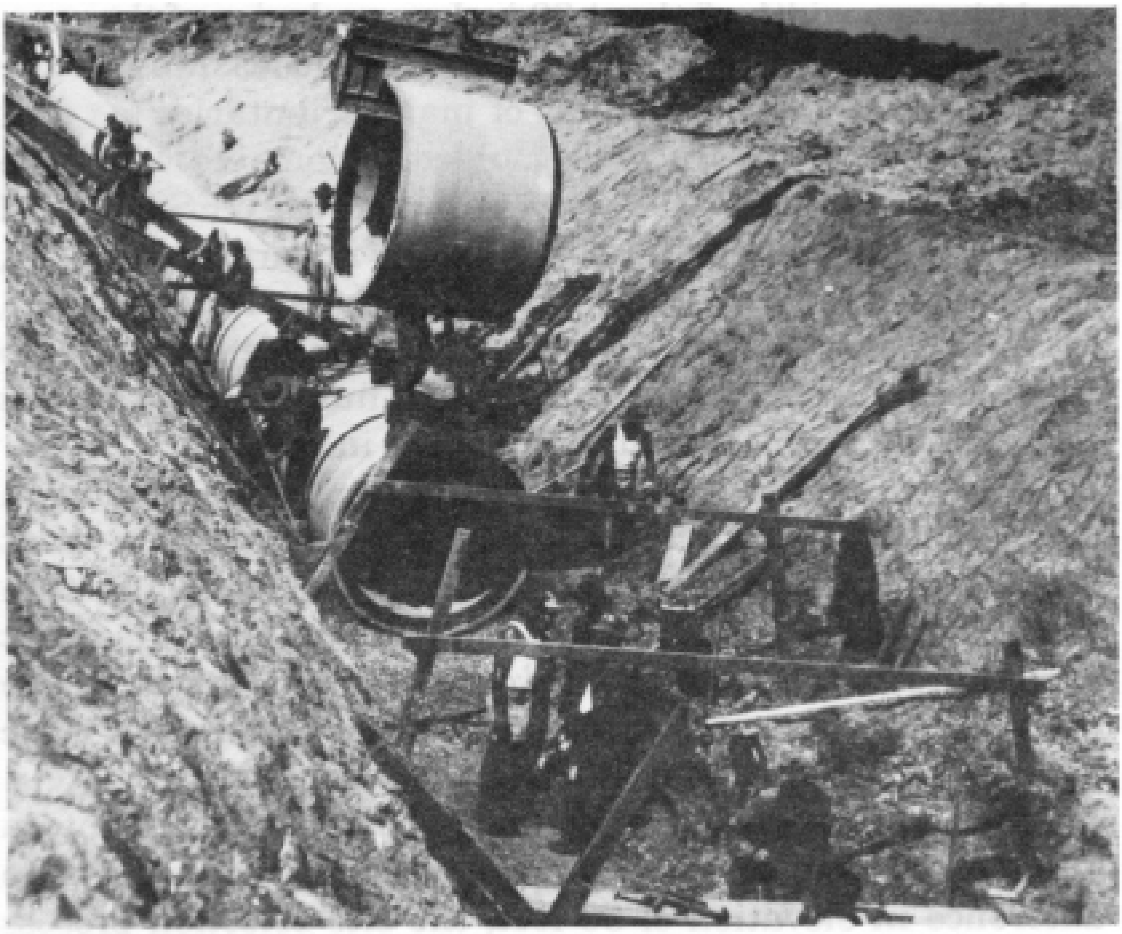
The feasibility of such a model as the MBM had been demonstrated by the Mississippi River Flood Control Model, operating at WES for about a decade. This earlier model, built to a scale of 1:2,000 horizontally and 1:100 vertically, created in miniature a 600-mile stretch of the Lower Mississippi River from Helena, Arkansas, to Donaldsonville, Louisiana. It proved invaluable by accurately reproducing observed floods and enabling researchers to portray the effects of flood discharges greater than heretofore experienced. It helped to establish levee grades, to check the effect and result of cutoffs in the main channel, to determine the character of storage in backwater areas, and to illustrate the operation of floodways.

The MBM was designed to the same scale as the model at Vicksburg. Thus, the drainage basin of 1.25 million square miles required that the model cover an area of approximately 200 acres. The network of streams 15,000 miles in length was nearly 8 miles long in the model. The model reproduced all existing and proposed flood control reservoirs, as well as levees, dikes, floodwalls, floodways, and other pertinent works. The size of the model streams may be illustrated by considering the Lower Mississippi River, which in some places is 1 mile wide and varies from 50 to 150 feet in depth depending upon the stage. In the model, this portion of the river would have a width of about 30 inches, exclusive of the overbank areas, and a depth of from 6 to 18 inches. Most of the Mississippi and large portions of major tributaries (as well as overflow areas) were to be molded in concrete while the intervening topography was covered with sod. WES designed the model to operate either as a whole or in part. Accordingly, portions of the main stem of rivers such as the Tennessee, Arkansas, and Missouri could be tested independently to study local flood control problems. Thus, the MBM was designed, in a sense, as many models in one.

To be whimsical, if one were a Lilliputian resident in this model conforming to its laws, he or she would be about ¾-inch tall, and because of the distorted scale, as thin as tissue paper. The normal 8 hours sleep would last but 2.4 minutes, while lunch hour would be only 18 seconds. The maximum discharge occurring in the model was about 2 cubic feet per second or about 1,000 gallons per minute.

Since the model location would be transformed into a giant relief map of the drainage basin with a maximum difference in elevation of 50 feet, the site selection process involved finding a location that would require the least possible amount of grading. The Clinton site was selected because it offered as close a resemblance to the finished topography as could be found near Vicksburg. Nevertheless, approximately 1 million cubic yards of excavation was needed to produce the required miniature basin. The grading of the site was unusual in that a topography consisting of ridges and valleys was artificially formed rather than a normal grading operation in which a more or less level surface is desired.

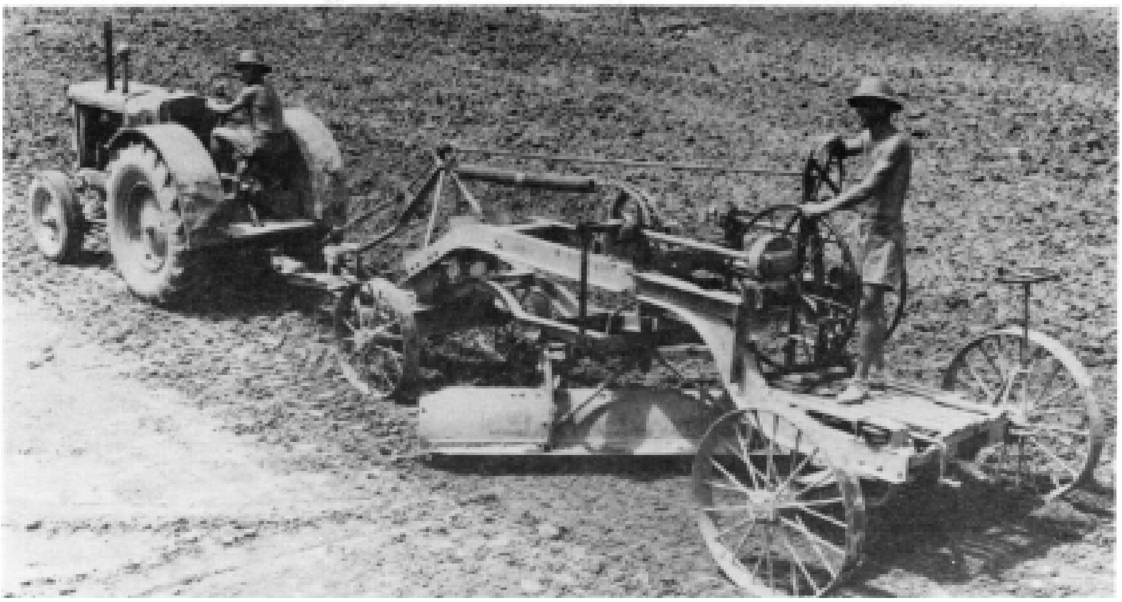
To simplify the field work of laying out the model, a rectangular grid of 100-foot squares was superimposed on the Bonne projection used for the site. In preparing the original grading plans, cuts and fills were projected for a haul of less than 500 feet in as many areas as possible. Limiting hauls to 500 feet was necessary because of the wheelbarrow-and-shovel nature of initial excavation operations. Fortunately, this labor-intensive effort did not last many months because WES obtained large earthmoving equipment which facilitated completion of the rough grading.



German prisoners of war place drainage system. (Waterways Experiment Station)

In grading the site, great care had to be taken in compacting the fill. Obviously any settlement would be disastrous to the model. The fills were made in accordance with standard procedures established by the WES Soils Division: placing the earth in 8-inch lifts, obtaining the proper moisture content, and then compacting with sheepsfoot rollers to obtain the desired density. Placing the fill in layers simplified the formation of the topography. WES prepared contour maps to show the extent of each lift, or of several lifts, in order to obtain the proper shape of a ridge or a valley.

Since the model streams themselves could not discharge rainfall occurring over the model area, a storm-water drainage system had to be provided; the annual rainfall at Clinton is approximately 55 inches. A separate water supply system provided the actual discharge of the model streams so that flows in the model could be regulated. To provide for surface

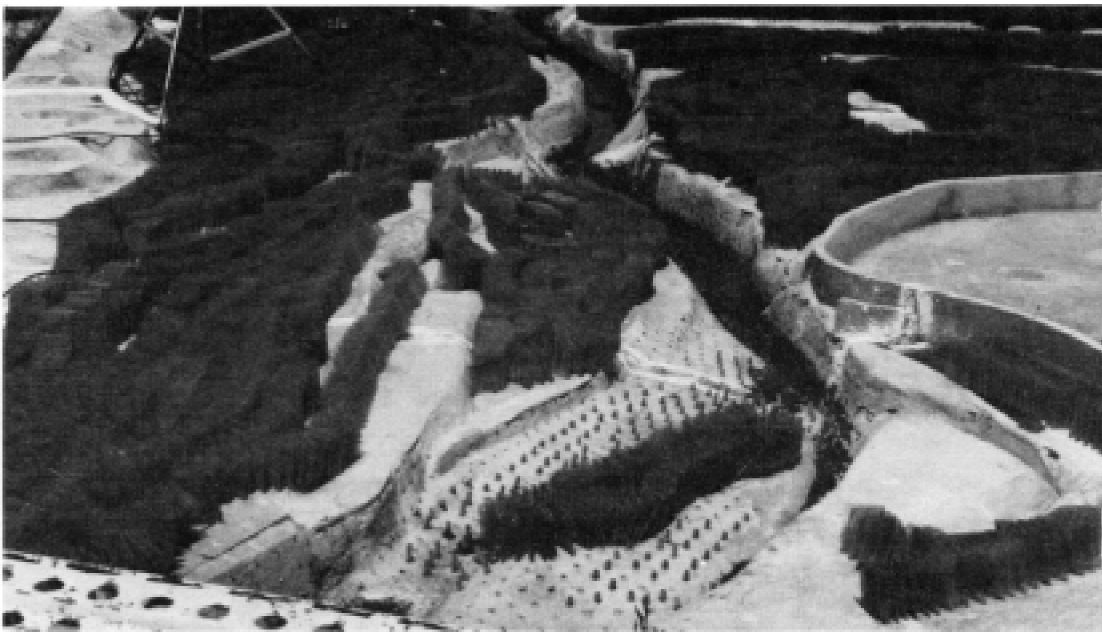


Grading the Mississippi Basin Model site *(Waterways Experiment Station)*

drainage, each miniriver valley was furnished with inlets to intercept water running in small V-shaped ditches on each side of the model streams. This water, in turn, was carried underground through laterals to outfall sewers discharging into a drainage canal surrounding the model. The length of pipe required amounted to some 85,000 feet, varying in size from 8 to 60 inches.

Corps division and district offices and other government agencies furnished the bulk of the physical data required for the design, construction, verification, and operation of the model. During the design and construction process, a large force was engaged in compiling, cataloging, and analyzing the following types of physical data: levee grades and alignments; location of railroads, highways, bridges, and similar construction; flood photographs; and steamflow data such as stage and discharge measurements, rating curves, and water-surface profiles.

Construction of the concrete portion of the model began in 1946 and continued at a varying pace due to inconsistent funding until its completion in 1966. This huge portion covered so large an area that it was built in sections with expansion joints between the sections to absorb the expansion and contraction of the concrete. Individual blocks were outlined on contour maps with a view toward keeping the



Detail of completed concrete portion of the Mississippi Basin Model. *(Waterways Experiment Station)*

blocks about 150 square feet in size and rectangular in shape with the ends perpendicular to the channel alignment: At first, WES constructed the model in place on a carefully prepared subgrade using sheet-metal templates cut to the cross sections obtained from topographic maps. However, because an expansive clay beneath the model caused excessive heaving, WES developed a new approach (the coutour method) in 1953. Sections of the model were molded on an assembly line, transported to the model site, and placed on concrete piles. This innovation effectively stabilized the horizontal plane of the model.

Channel roughness elements consisting of brushed and scored concrete, concrete ridges, and concrete as well as brass blocks were installed to size and spacing determined from computations and pilot model studies. Folded screen wire cut to the scale of the average height of trees was placed in the model in accordance with information drawn from aerial photographs. Although construction of the model continued until 1966, individual sections were in operation by 1949. As a section of the model was completed, the roughness added, and instruments installed, it was verified (made to reproduce historical occurrences in nature) and operated for local testing.

The verification process involved the use of historical data to refine the model. A recent flood of considerable magnitude was selected to verify each reach of the model. The model equivalents of the flood flows, from the low stages to the crest, were introduced at the model inflow points and the channel and overbank roughnesses were increased or decreased until the model stages replicated the historical data. Once verified, the model could be used to help forecast probable future occurrences.

Automatic instrumentation was a major, innovative feature of the model. The designers realized that a staff of 600 personnel would be required to manually operate the model. Therefore, the engineers in charge decided to explore the feasibility of using automatic controls. Nearly four years, 1943 to 1947, were devoted to studying and developing these instruments. WES contacted more than 125 commercial firms and conducted many tests. These tests disclosed that the available instruments could not meet the model's rigorous accuracy requirements. After the war, WES prepared specifications, invited bids, and obtained this highly specialized equipment.

Close cooperation among the interested Corps offices was essential to the proper construction and operation of the far-reaching model. Consequently, in 1945 the Corps created a Mississippi Basin Model Board to determine policies and programs for the model's operation and testing. The committee consisted of commanders of the Corps divisions within the basin, the WES director, and a representative of the Office of the Chief of Engineers. This policy-making body was supported by various staff-level committees that helped develop plans, programs, and procedures.

In April 1952, the model dramatically demonstrated its value in a field for which it was not originally planned—forecasting the progression of a flood. WES was asked if the Missouri River section of the model could be operated in connection with a major flood. That portion of the model had been completed and verified and was ready for use. During 15 crucial days, constant communication was maintained between the Missouri River Division, the Omaha and Kansas City districts, and the Waterways Experiment Station. The data furnished by the model were water–surface profiles, crest discharges, stage and discharge hydrographs, and the identification of critical locations where levee raises were necessary. The information furnished by the model tests was of incalculable value in aiding evacuations and supporting flood-fighting activities.

In April 1973, WES used the model to assist in a flood fight on the Lower Mississippi River. In the fall of 1972, the Mississippi River basin experienced heavy rainfall. The flood control reservoirs along the tributary streams began to fill and the ground became saturated. In the spring of 1973, a serious flood developed. On 12 April, problems developed at the Old River control structure as a wing wall failed and a scour hole developed in front of the structure. The model was put into operation to help determine the effect of opening Morganza floodway on the flow conditions at Old River and on stages in the Atchafalaya basin. The model operated 24 hours a day for the remainder of the flood to help determine which levees were in danger of being overtopped, what portions needed to be raised to contain the flood, and how the operation of Morganza floodway would affect flood stages.

The Mississippi Basin Model, employed on an intermittent basis since the major series of tests concluded in 1971, exceeded the expectations of its inventors. The report-filled shelves of the WES Research Library attest to its role in improving flood control and related practices on the Mississippi and a host of other rivers. It also (in conjunction with many other WES endeavors) confirmed the place of small-scale hydraulics research within the Corps' civil works program. Conceived during World War II, built partially with POW labor, and used for a host of activities, the Mississippi Basin Model has been a good and reliable soldier.

Sources for Further Reading

For an excellent overview of the founding of the Waterways Experiment Station, see Herbert Vogel, "Origin of the Waterways Experiment Station," *Military Engineer* (March–April, 1962): 135–36.

Details regarding the Mississippi Basin Model's construction and use may be found in "Hydraulic Model of the Mississippi," *Engineering News–Record,* 134 (May 31, 1945): 766–769, and J.E. Foster, *History and Description of the Mississippi Basin Model,* MBM Model Report 1–6 (Vicksburg, Mississippi: Waterways Experiment Station, 1971).

Special thanks is offered to Terry Winschel, historian, Vicksburg National Military Park, for sharing his unpublished essay on the Clinton prisoners of war camp.